EFFECTIVENESS OF STANDARDS FOR MITIGATING DAMAGE IN CONCRETE DUE TO MATERIALS DEFICIENCIES

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Toy S. Poole

- Education:
  - BS Chemistry, PhD Zoology
- 32 y - Corps of Engineers.
  - Retired 2010
  - Live in Austin, Texas
- Currently employed:
  - CTL Group
  - Consulting with Corps of Engineers
- ASTM since 1985
  - Committees C1 (cement) and C9 (concrete)
  - Board of Directors

Background

- R&D ⟶ Standards ⟶ Application
- Much progress starting in the early 20th century
- Still gaps in standards that continue to cause problems
- Process of filling these gaps seems to have stalled in some cases
- Objective of presentation is to explore some of these and cogitate on causes

Background

- Early History (modern era)
- Standards
  - ASTM C1 1902
  - ASTM C9 1914
  - AASHTO 1914
  - ACI ???
- MRD stds >1930

Bellafontaine, OH - 1891

Critical Points

- Determination of Specification Limits
- Field Service Records
- Precision of Test Methods
- Sampling of Materials

Origin of Specification Limits

- Field-Service Records
- Lab test results
- Origin often unknown
  - Inadequate or non-existent historical records.

Field Service Records

- Analysis of old structures and comparison with new construction
  - Similar materials
  - Similar exposures
  - Sufficient age
  - Availability of “as builts”
- Conditions rarely met

Poor Precision of Test Methods

- Common in concrete mtls TM's
- Largely ignored
- Many problems in acceptance testing - $$$$
- C78 (flex beam) good example

Sampling of Materials

- Acceptance often on manufacturers certification (mill certificate)
  - Typically based on averaging
- User sampling is often by a single grab sample
- Significant variability in product stream
  - Aggregates – spatial variation in quarry
  - Manufactured – variation in raw materials, processes
- Result: What you test may not be what you get

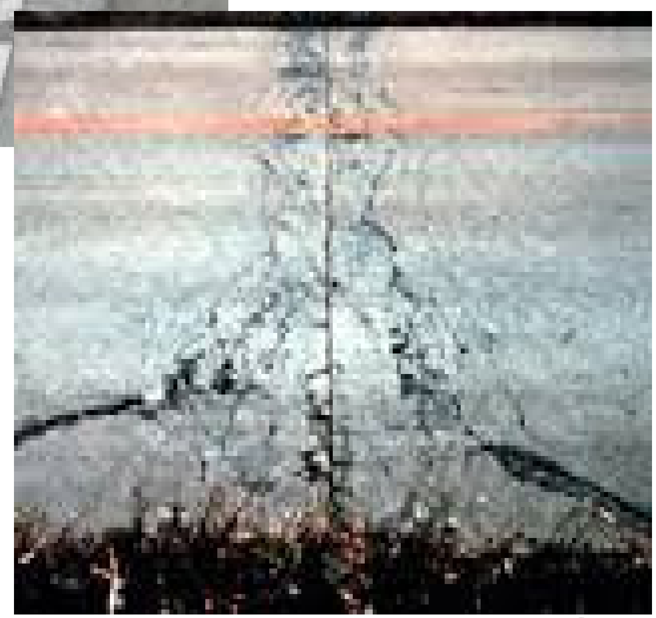
Examples

- Instability of aggregate to F/T cycles
- Air Entraining to mitigate F/T damage
- Alkali-aggregate Reaction
- Variation in coal fly ash

Damage to Aggregate – Freezing and Thawing

- D-cracking (durability cracking)
- 9% expansion of freezing water in confined space
- Depends strongly on microstructure of rock
  - Coarse pore structure usually drains – no damage
  - Fine pore structure holds water - damage

D Cracking – Concrete Pavements



>Usually with sedimentary-rock aggregates

>Usually associated with joints in pavement

Acceptance-Testing Problems

- High level of uncertainty in test methods
- Owner vs Producer disputes common
- False rejections - costly to contractors
- False acceptance - costly to owners
- Sampling – major issue

ASTM C88 (1931) – “Sulfate Soundness Test”

- Wetting & drying
- simulation of freezing and thawing – changes in salt crystallization
- Metric is mass loss due to fracturing of rock

C88 Continued

- Short duration test
- Simple to execute
- Relatively cheap
- Poor precision
- Very aggressive test
- Origin of specification limits unknown
- A replacement test is needed

ASTM C666 (1971) – Rapid Freezing and Thawing

- Simulates actual freezing and thawing conditions
- Laboratory fabricated concrete tests specimens or field cores
- Two alternatives (user selected)
  - Freeze and thaw in water (Procedure A)
  - Freeze in air, thaw in water (Procedure B)
- Metrics
  - Changes in modulus
  - Length Change
  - Mass Loss

C666 Testing

H-3185B

H-3185SD

C666 Continued

- Precision information incomplete
- Disagreement on interpretation of results
- Long test period (2 – 5 months)
- Expensive
- Validation difficult
- Needs a major review

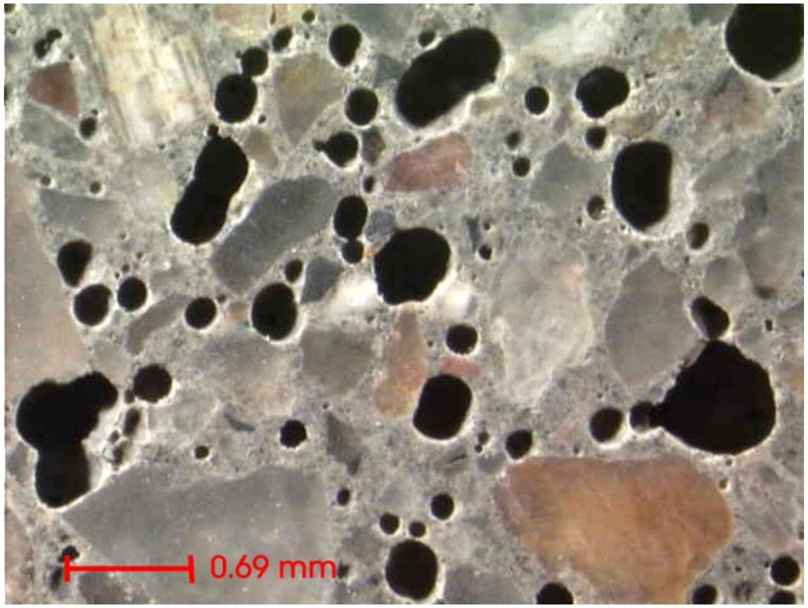
Air Entrainment: Mitigate F/T Damage to Cement Paste

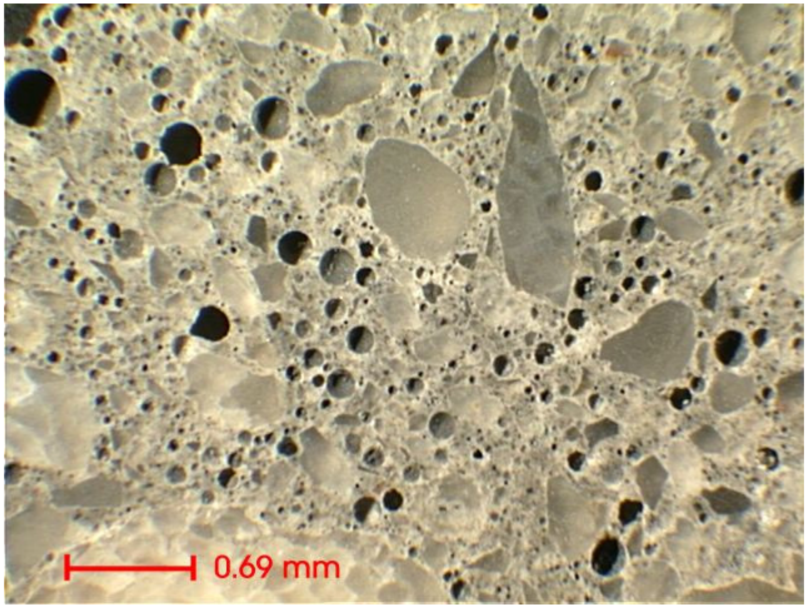
- We know how to effectively mitigate damage - just don't always do it
- Damage mechanism is same as in D-Cracking
  - But in cement paste (not aggregate)
- Mitigated by air entrainment

Air Entraining

- Basic mechanism: small air bubble in cement paste provides a pressure relief system for water expansion immediately before freezing Discovered in 1940’s
- Amount, size and spacing of air voids are critical
- Relatively delicate process to control

Air Entraining Problems

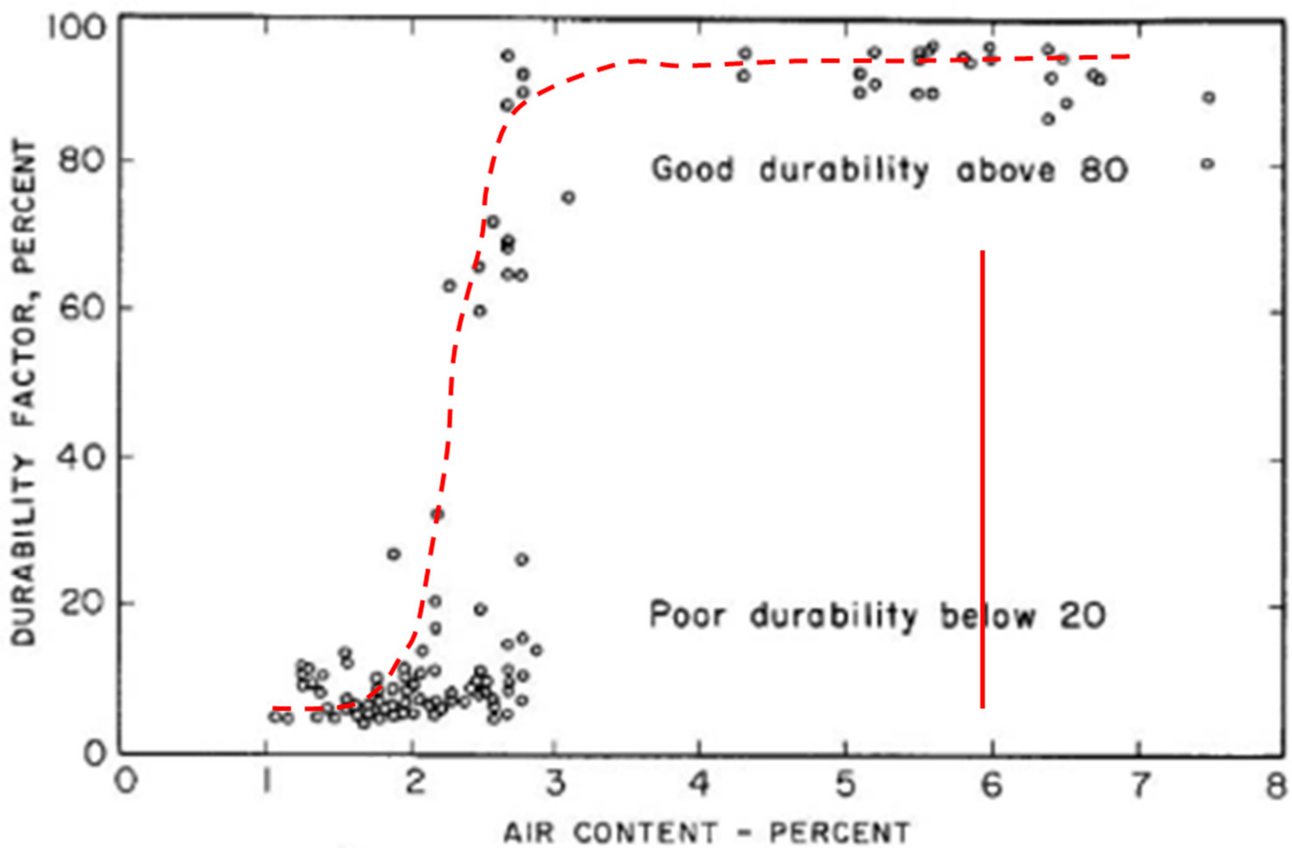




Deficiencies in Air – Early Damage

Deficiencies in Air – Later Damage

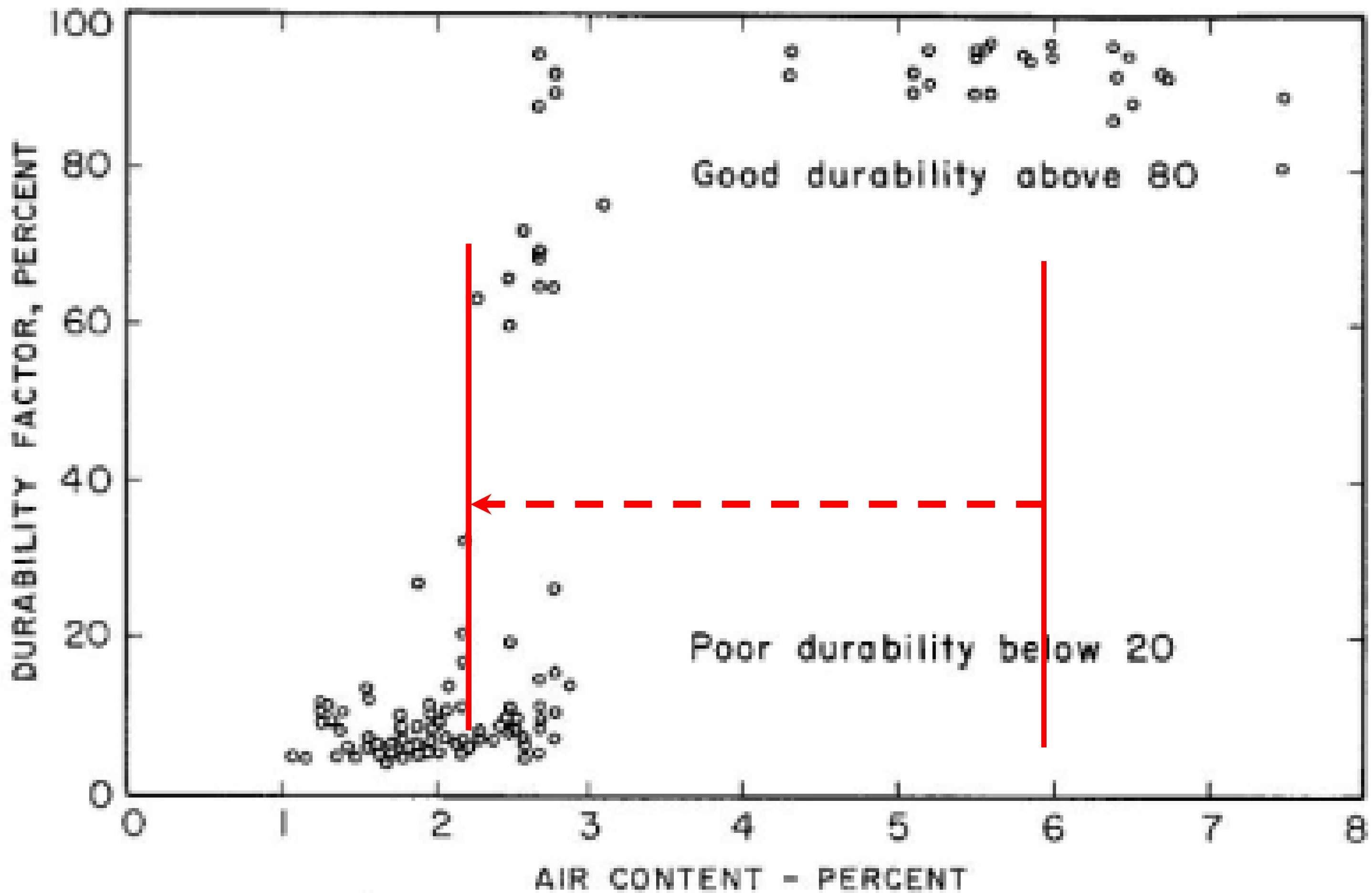
Construction Practice – Total Air



Failures: Whose Fault ?

- Spec's
  - Limits on total air in front of the paver
  - No limits on total air after consolidation
  - No consideration for void size and spacing
- Compliance with specification does not insure performance
- Loss of air occurs during consolidation

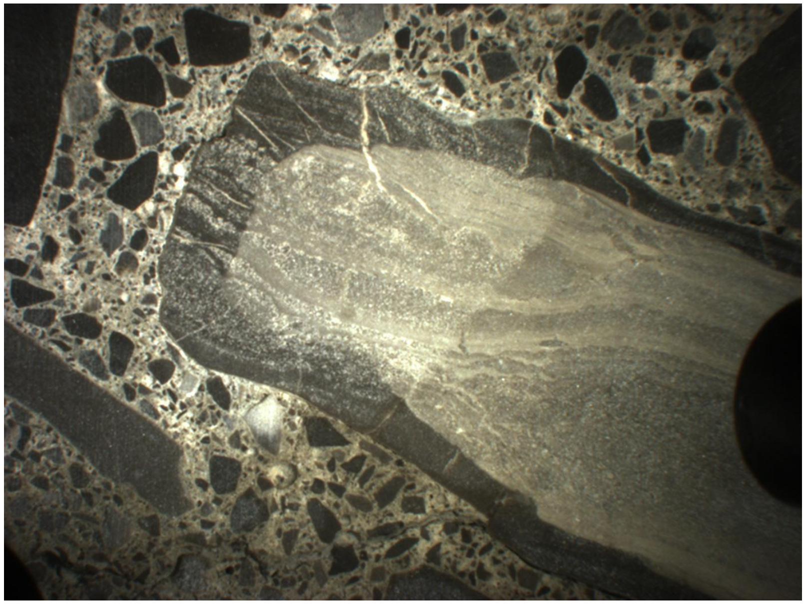
Problem – Loss of Air during consolidation



Alkali-Aggregate Reaction

- Mineral components of some aggregates unstable at very high pH
  - Sodium and potassium salts causes high pH
- Forms expansive compounds within aggregate particle
- Resulting tensile forces crack concrete
- Relatively slow and long lasting

Distressed Aggregate Particles



Forms of AAR Presentation

Ft. Campbell, KY – Sub-cracking expansion

Carters Dam, GA – aggregate variation

AAR – General Problem

- Basically understand the reaction mechanisms
- Basically struggle to accurately determine
  - If the reaction will actually occur
  - When and if damage will occur
  - Whether mitigation will be effective
  - The long-term prognosis of the phenomenon

Standards

- Test methods – expansion of laboratory specimens
- Test methods may not simulate actual service conditions all that well
- Validation against field conditions is difficult
- Testing suffers
  - Poor test method precision
  - Weak sampling schemes - particularly sedimentary rock quarries

Standard Testing

- Considerable ongoing work on test method revision
  - New concepts
  - Improvement in precision
- Sampling continues to be a problem
  - Variation in product streams can be significant and undetected

Variability in Coal Fly Ash

- Coal Fly Ash
  - Has become an important part of concrete practice
- Variability
  - Common issue
  - Significant impacts during construction

Fundamental Problem

- Coal power plants have major concern
  - Environmental issues
  - Efficiency of energy extraction from coal
  - Economical coal supplies = variation

- Quality of fly ash is not a high priority

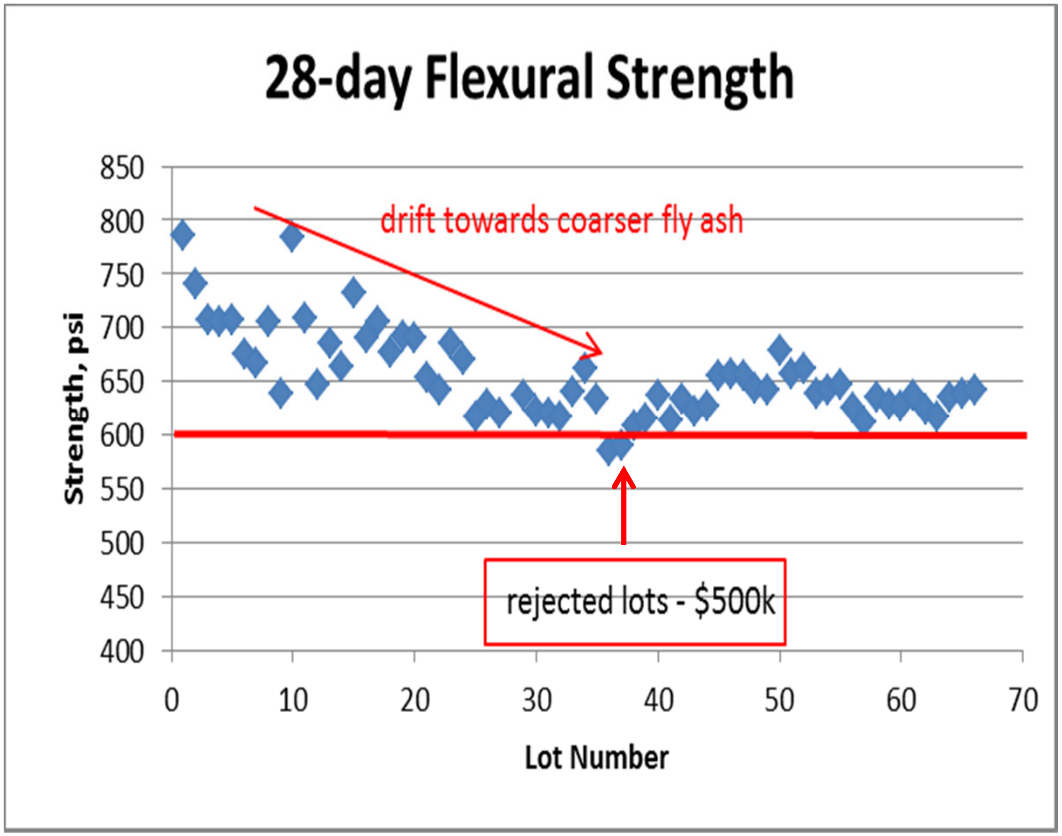
Fly Ash Storage Failure

Variable fly ash properties

- Fineness
  - strength
- Chemistry
  - Loss of workability
  - ASR
  - Time of setting
- Residual carbon
  - Air entraining

Fineness drift example - PCCP

- Fly ash fineness drifts over a period of a few weeks
- Affect on construction
  - strength drift
  - Rejected lots
  - Replacement $$$
- Specification weak on uniformity



Concluding Remarks

- Standards have had a large positive effect on promoting durability
- Still important work to be done
- Contractors usually motivated by cost of construction
- Motivation must come from Users

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